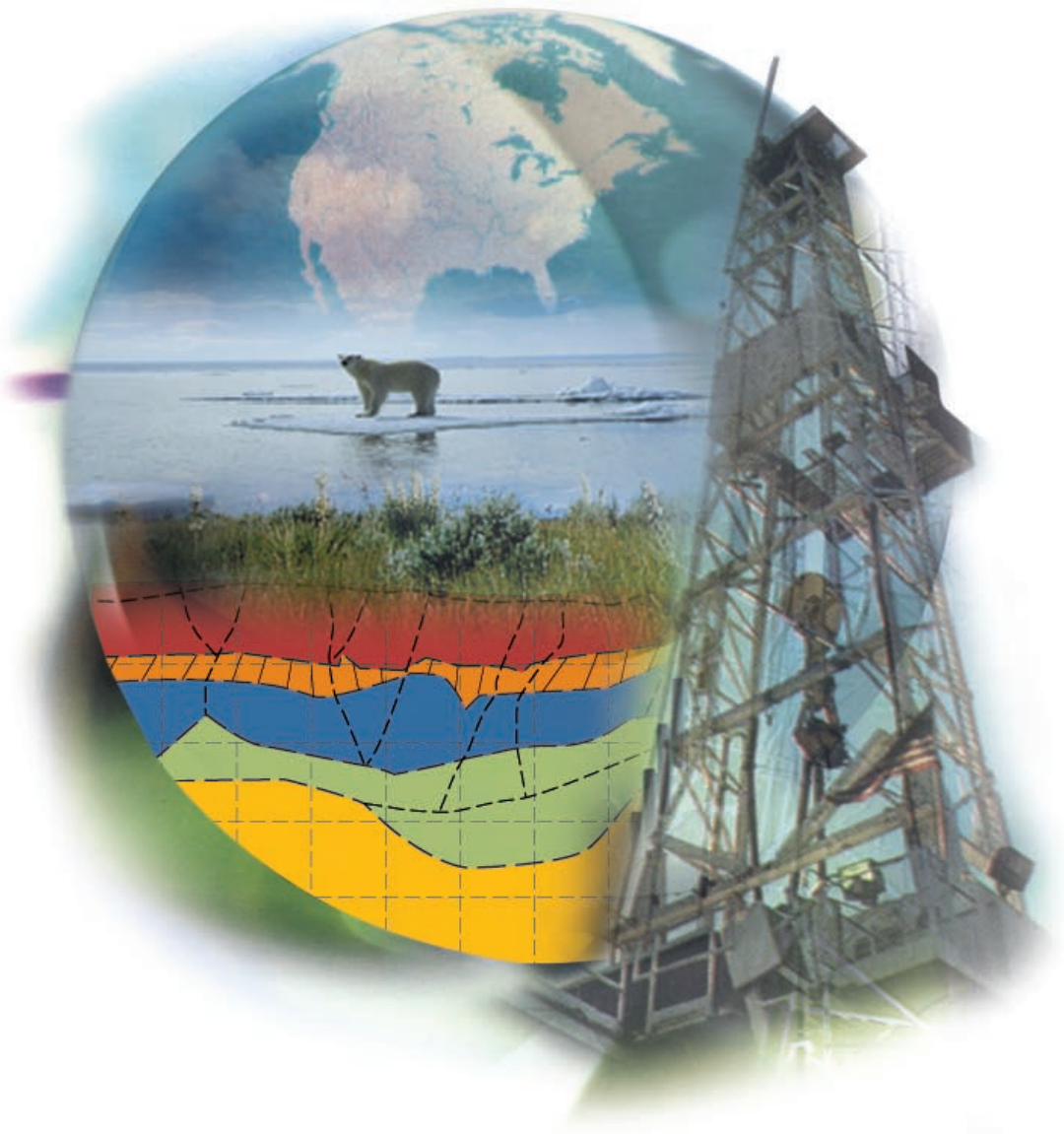
U.S. Department of Energy
Office of Fossil Energy



Environmental Benefits of Advanced Oil and Gas Exploration and Production Technology

Operations in Sensitive Environments

From the tundra of Alaska to the wetlands of Louisiana, a host of advanced technologies enable the oil and gas industry to produce resources far beneath sensitive environments.

Smaller Footprints, Less Waste, Lower Impact

A growing proportion of the Nation's remaining untapped resources exist in sensitive environments—which are as varied as the mountains and tundra of Alaska, offshore California, the deepwater Gulf of Mexico, and the wetlands of coastal Texas and Louisiana—and even in the midst of bustling urban centers. Moreover, many of these fragile areas reside on our Nation's public lands, requiring industry and government to work collaboratively as stewards of these treasures. Industry simply cannot afford failures in these fragile settings. Over the last four decades, the industry has developed increasingly innovative technology and approaches for conducting operations in sensitive areas, improving not only environmental performance, but economic performance and resource recovery as well.

Technology that enables safe and efficient exploration and production beneath sensitive environmental areas includes new 3-D seismic and 4-D time-lapse imaging, satellite imaging, aeromagnetic sensing, and ground-penetrating radar. New acoustical and vibration devices have also replaced explosives for generating seismic signals onshore and offshore, reducing noise and protecting marine and animal life. And new directional drilling, extended-reach drilling, and multilateral drilling technology, coupled with measurement-while-drilling systems, allow industry to safely produce resources far beneath sensitive environments with less surface disturbance.

arctic environments

Photo: The Stock Market

Established by President Theodore Roosevelt, southern Alaska's Kenai National Wildlife Refuge is home to moose, Dall sheep, mountain goat, caribou, coyote, wolf, grizzly bear, black bear, lynx, wolverine, beaver, small mammals, birds, and salmon. It is also home to the Swanson River oil field. Unocal, operator of the field since 1992, received the "National Health of the Land" award in 1997 from the U.S. Department of the Interior for environmental excellence at Swanson River.

To ensure that its oil and gas operations within the refuge are conducted in an environmentally responsible manner, Unocal has implemented state-of-the-art practices. Plastic pipeliners have been installed on 28,000 linear feet of metal gathering lines and flow lines to avoid the potential for leaks. Specially trained dogs are used for the early detection of underground pipeline leaks. A water filtration and treatment system collects and processes runoff to prevent problems that may arise from the leakage of hydrocarbon compounds from old petroleum storage facilities. And groundwater-monitoring wells ensure that if contamination of groundwater occurs, it is quickly detected. Together, these measures protect a habitat that will be a refuge to wildlife and an inspiration to visitors for many generations to come.

Source: Unocal Corporation, 1996–97 Health, Environmental, and Safety Report

From Alaska's North Slope to Kenai . . . Greater Protective Measures

Logistical barriers—posed by extremely low temperatures, freezing and thawing of the tundra, and remote locations—once limited drilling in arctic environments. Today's operators not only cope successfully with these challenges, but also institute protective measures appropriate to sensitive environments. Improvements over the past 40 years have dramatically reduced industry's footprint on the fragile tundra, minimized waste produced, and protected the land for resident and migratory wildlife. Environmental advances have also dramatically reduced costs of conducting oil and gas activities. Industry innovations include:

Ice pads and roads

As ice construction technology and equipment have improved in recent years, bitter-cold temperatures have been turned to good use. Ice-based roads, bridges, drilling pads, and airstrips have become the standard for North Slope exploration projects. Not only is ice-based fabrication cheaper than gravel, it leaves virtually no footprint on the tundra; ice structures simply thaw and melt in the spring. In recent years, this approach has been further improved: BP Exploration (Alaska) Inc. (BPXA) has successfully built insulated ice pads for drill rigs, permitting the company to extend its exploratory drilling season significantly and to reduce both seasonal mobilization of equipment and drilling footprints, as well as operating costs.

Low-impact exploration approaches

When exploratory wells are too far from existing infrastructure to build ice roads cost-effectively, alternate means of transportation are now used almost exclusively. Large all-terrain vehicles with huge, low-pressure, balloon-like tires carry substantial equipment loads across the tundra, leaving practically no tracks. To protect the North Slope's fragile tundra, exploratory operations are now conducted exclusively during the winter.

Advanced drilling technology

Advances in drilling technology have played a major role in increasing North Slope productivity and in benefiting the environment. Horizontal drilling, introduced in 1990, now accounts for 90 percent of the wells drilled in Prudhoe Bay. Whereas early horizontal wells in Prudhoe penetrated only 500 to 800 feet of reservoir laterally, technology advances

recently enabled a North Slope operator to penetrate 8,000 feet of reservoir horizontally, greatly increasing contact with oil-bearing sands. If the bay were developed today using horizontal drilling, only 11 drill sites would be needed, compared to the 42 required in the 1970s. The area's first multilateral well was drilled less than two years ago; today there are 10 multilateral wells in the area, two of which used coiled tubing rigs.

A technology recently introduced jointly by ARCO-Alaska and BPXA is truly revolutionary. Called through-tubing rotary drilling, it allows an operator to drill a new well through the existing production tubing of an older well, saving both time and money. Another recent North Slope breakthrough is "designer wells" technology, an advanced form of directional drilling, where wells curve around and behind geological barriers to reach small pay zones. Extended-reach drilling is also greatly improving resource recovery and environmental protection in the area. Using extended-reach drilling, North Slope operators expect to develop the area's newest giant field, the 1-billion-barrel Alpine field, with 100 wells from only two drill sites, minimizing the drilling footprint. At Niakuk, operators have used extended-reach drilling to tap many offshore locations from a single drill pad on Heald Point.

By increasing resource recovery and reducing drilling costs, all these advances have benefited the economics of North Slope operators. By minimizing the number of wells drilled, drilling footprints, and waste volumes, they have benefited the environment as well.

Reduced footprint

Significant reductions in the size of production-related facilities have shrunk the footprint of North Slope operations. ARCO-Alaska's Kuparuk field, for example, uses a 55-acre facility as an operations base for contractor support, compared with a similar 1,000-acre facility in the original Prudhoe Bay field. If the entire Prudhoe Bay oil field were built with today's technology, its footprint would be 64 percent smaller than its current size—the area impacted by drilling pads would be 74 percent smaller, roads would cover 58 percent less surface area, and oil and gas separating facilities would take up 50 percent less space. Today, new production pads are up to 70 percent smaller than the original Prudhoe pads, and spacing between wellheads has been reduced dramatically. In addition, facilities are now built more quickly than previous ones, further reducing construction costs and disturbances to the environment.

Improved methods for site restoration and enhancement

In the fragile North Slope ecosystem, site restoration and habitat enhancement are a vital part of post-production. As North Slope operators continue their search for advanced environmental solutions, new technology and practices have been developed to restore areas affected by E&P activities. For example, at a number of abandoned gravel mining sites in floodplains, BPXA and ARCO-Alaska flooded the sites to create large pools and lakes that serve as overwintering habitats for fish and predator-free nesting sites for waterfowl, a practice encouraged by the Alaska Department of Fish and Game.

Revegetation of areas affected by gravel construction and drilling is also an important restoration technique. Between 1985 and 1989, BPXA and the U.S. Department of Fish and Wildlife worked jointly to restore the habitat along the 10-mile-long Endicott road. Researchers found that transplanting arctic pendant grass successfully revegetated disturbed aquatic sites. In 1988, BPXA began restoring its BP Pad, an exploratory drilling site first used nearly 20 years earlier. After equipment and debris were removed, the well was plugged and construction gravel was excavated from the site. BPXA seeded the wellsite and surrounding tundra with three types of native grasses and fertilized the area. A snow fence was erected to create snowdrifts that would increase moisture levels at the site. Within three years, the area's native vegetation had been restored.

wetlands, coastal, and offshore

Wetlands and Coastal Operations . . . Ecosystems Preserved

Growing national awareness of the environmental significance of wetlands and coastal areas has inhibited E&P operations in certain areas. Where operations are conducted, the industry takes extreme care to minimize all associated risks. Technology such as directional drilling is critical in minimizing surface disturbance in wetlands and coastal areas. Advanced site restoration methods for these sites are also a vital industry pursuit.

Today, operators employ a variety of advanced drilling and production technologies to operate safely in sensitive wetlands and coastal areas. In the wetlands of south Louisiana, for example, ARCO Oil and Gas Co. employed innovative drilling technology to conduct operations that were both environmentally safe and cost-effective. By utilizing an efficient closed loop solids control system, ARCO reduced both its drilling footprint and its waste volumes.

A recent drilling operation on Padre Island National Seashore on the Gulf Coast of Texas, the longest remaining undeveloped barrier island in the world and one of our Nation's most treasured Federal lands, also demonstrates this commitment to environmentally responsible operations. In drilling an exploratory well near the seashore's Malaquite Beach, Bright & Co. undertook extensive cooperative planning and regulatory compliance efforts with Federal and State agencies, while utilizing state-of-the-art drilling and site restoration technology to minimize impacts. For example, drilling operations were conducted with a diesel-electric rig, which operated at extremely low noise levels. Most of the rig's components were wheel-mounted, reducing the number of equipment loads moved across the beach. The drilling system's mud pumps and draw works were powered by electric motors—using electric motors not only reduced air emissions from the site, it minimized the possibility of harmful oil leaks.

Since the targeted pay zone was located under a large wetlands area, directional drilling was employed to drill beneath the sensitive area, greatly reducing environmental impacts. During its operations, Bright & Co. utilized an advanced polycrystalline diamond compact bit in order to maintain the well's angle and direction. Finding no productive zones in the well, Bright & Co. plugged and abandoned the well, restored the site to its original contours, and reseeded with native grass.

These are but two examples that represent the oil and gas industry's commitment to operate responsibly in sensitive wetland and coastal areas. This commitment is recognized outside the industry as well. Robert J. Potts, State Director of The Nature Conservancy's Texas office, recently noted, "The Nature Conservancy of Texas has a long history of cooperative partnerships with the oil and gas industry. Several of our preserves are home to ongoing oil and gas operations while at the same time providing excellent habitat for wildlife."

Offshore Operations . . . Operating Safer, Smarter, and Deeper

From the Gulf of Mexico's subsalt plays, to the hostile North Sea, to offshore West Africa and Brazil, as the offshore oil and gas industry moves into deeper and more remote settings in search of new resources, operators are utilizing a variety of advanced technologies to protect the environment, enhance worker safety, and increase recovery. Offshore operations, which occur in the midst of complex underwater ecosystems consisting of hundreds of aquatic species and flora types, require extreme care and planning. Today, advanced technology is meeting these challenges.

Advanced 3-D seismic and 4-D time-lapse data processing and imaging technologies, coupled with satellite-derived bathymetry and gravity data, enable offshore operators to locate oil and gas resources far more accurately than only one decade ago, resulting in fewer dry holes, less drilling, and greater resource recovery. For example, the Gulf of Mexico's subsalt play, completely undeveloped 10 years ago, is now one of the world's hottest offshore settings, thanks to state-of-art subsalt imaging technology such as Full Tensor Gradient (FTG) imaging and marine magnetotelluric surveys.

Not only is the industry finding and developing resources in more remote and challenging settings, it is significantly enhancing worker safety and pollution control in the process. Today, nearly all Outer Continental Shelf operators are collaborating with the Minerals Management Service and other Federal agencies to implement Safety and Environmental Management Programs (SEMP), voluntary, nonregulatory strategies designed to identify and reduce risks and occurrences of offshore accidents, injuries, and spills. As a result, this commitment to safer and smarter operating practices has enabled the offshore industry to practically eliminate oil spills from offshore platforms.

Today's advanced subsea drilling and completion technology also enables the industry to operate effectively and safely as it moves into deeper and more hostile areas. For example, advanced subsea blowout preventers (BOPs) maintain well control in deepwater environments. Current deepwater BOPs, located on the sea floor instead of at the platform level, continuously monitor subsurface and subseabed conditions.

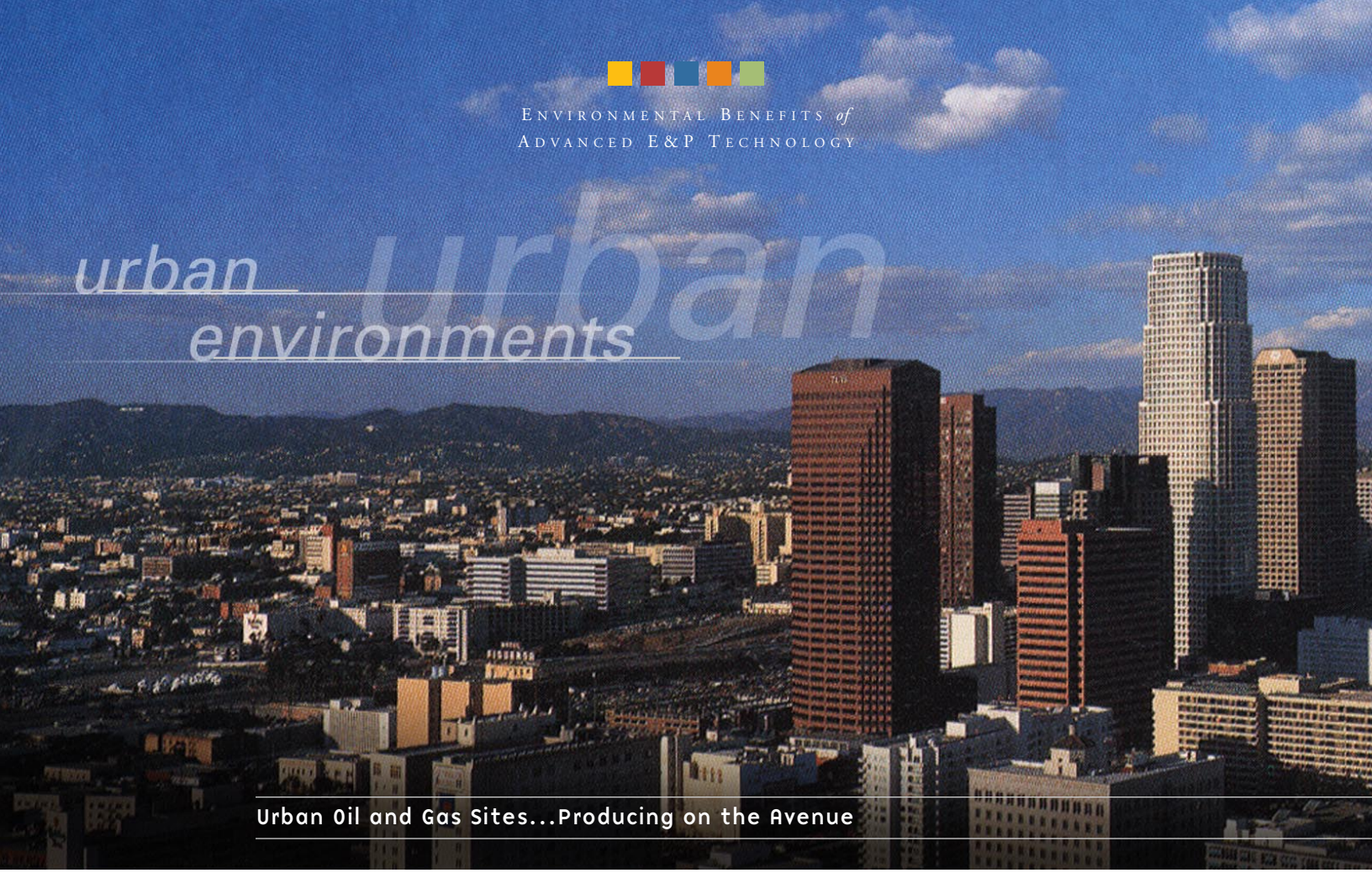
In the event of a well control emergency, advanced "intelligent" subsea trees allow live wells to be shut in quickly under a variety of well conditions and operational circumstances. Moreover, current measurement-while-drilling technology enables drillers to accurately steer a deepwater relief well to regain well control if necessary.

Other recent advances in subsea technology are permitting operators to access more remote deepwater resources with minimal disturbance to the surface and subsea environments. Subsea production systems, aided by new-generation remotely operated vehicles, all-electric subsea monitoring and

control systems, and minimally sized umbilicals, are now able to connect remote subsea satellite wells to host production facilities tens of miles away. For example, Shell Exploration and Production's Mensa subsea production system, located in over 5,000 feet of water in the Gulf of Mexico, produces natural gas from three subsea wells connected to a subsea manifold sitting on the sea floor, which is then tied back to an existing shallow water production platform (West Delta 143) over 60 miles away via a 12-inch carbon steel flowline. At West Delta 143, a computer-based system monitors the operational status of the wells and other subsea equipment, with the capability to open and close the wells if necessary.

On the whole, these technologies are allowing the offshore industry to venture into deeper waters than ever before, while protecting marine life and subsea habitats. As a result of these advances, operators are able to locate and produce more offshore resources, with less drilling, fewer dry holes, less waste, and minimal impact.

urban environments



Urban Oil and Gas Sites...Producing on the Avenue

"Hundreds of visitors from all around the world visit our islands every year, many of whom come here specifically to learn about this model of oilfield development in a sensitive, urban environment. I haven't met a person yet who doesn't come away impressed."

James M. Davis
President of ARCO Long Beach, Inc.

Diverse images come to mind when one envisions oil and gas exploration and production sites: scorching hot deserts; windblown, tumbleweed-strewn prairies; vast frozen tundra; 20-foot-high waves and churning whitecaps; and distant mountain ranges. But few people realize that the petroleum industry also explores for and produces oil and gas in the midst of our Nation's largest cities. In recent decades, the industry has successfully met the unique challenges posed by these urban environments, where operations are frequently visible for all to see. Advanced technology has been a key to meeting the challenges.

Urban operations are as varied as the cities in which they are located. For example, visitors to Oklahoma City are greeted with the sight of pumpjacks and other production equipment and facilities—Oklahoma City's Will Rogers World Airport is located in the heart of an active oil field. The Los Angeles Downtown oil field, located in the shadow of the Santa Monica Freeway and near the Los Angeles Civic Center, has produced nearly 14 million barrels of oil and 21 billion cubic feet of natural gas over the past 30 years. State-of-the-art fire prevention and gas leak detectors ensure the safety of the surrounding community. In the Southern California beach community of Huntington Beach, oil and gas development occurs both onshore and in State offshore waters. Onshore, production equipment located on the beach operates as runners and bicyclists enjoy a nearby boardwalk. Offshore, extended-reach drilling technology has permitted operators to tap nearshore reserves from onshore deviated wells.

Perhaps the most remarkable story of urban operations today is ARCO Long Beach, Inc.'s 43,000-barrel-per-day operation at the East Wilmington unit, located in the City of Long Beach's scenic harbor. The East Wilmington unit is part of the giant Wilmington field, one of the Nation's largest. Production at East Wilmington occurs from four manmade islands—built on 640,000 tons of boulders and 3.2 million cubic yards of sand dredged from the harbor, and concealed by palm trees, flowers, concrete sculptures, waterfalls, and colorful

nighttime lighting. These islands represent the centerpiece of a collaborative solution between the industry and the City of Long Beach to tap the harbor's resources without harming its natural beauty.

Daily operations at East Wilmington are a testament to advanced technology and its success in protecting the environment. Rather than using relatively noisy and polluting diesel engines for drilling and pumping, operations make use of quiet and clean electric power. To shelter operations from public view, drilling rigs are covered by structures built to resemble high-rise buildings, and wellheads and other support facilities are located below ground.

In recent years, advanced technology has played a critical role in expanding the field's production and maintaining a high level of environmental performance. In 1996, ARCO implemented the largest waterflood in California's history at the field. This oil recovery technique, combined with advanced hydraulic fracturing and horizontal drilling technology, has increased daily oil production by approximately 30 percent. Moreover, ARCO is expecting a recently conducted 3-D seismic survey to further boost production.

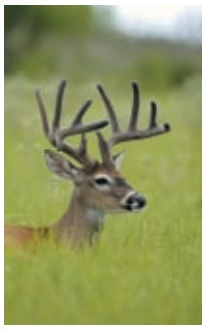
ARCO is now using chemical treatment for final separation of produced water and oil rather than gas-fired heated vessels, reducing air emissions by 60 percent. The thousands of tons of sand and shale removed during operations are now reinjected into a dedicated well on one of the production islands, rather than hauled to a landfill. Moreover, ARCO is currently testing the viability of using treated sewage effluent in its waterflood operations in order to reduce the amount of fresh water currently needed.

Advanced technology has enabled the petroleum industry to increase recovery of oil and gas resources wherever they may occur—including urban environments. As a result, oil and gas development operations are able to coexist, even thrive, in urban surroundings, as operators successfully minimize noise pollution, air emissions, and surface and visual disturbances.

Oilfield development in Long Beach harbor is a model urban operation.

public lands public benefit

Joint Stewardship Protects Our Public Treasures



Stewardship of public lands requires close collaboration of industry and government.

Many of our Nation's oil and gas resources are located on public lands, over which the Federal government has management and resource protection responsibilities. These public lands range from wildlife refuges to national parks and seashores to the Outer Continental Shelf. Operating in these national treasures entails complex logistical, organizational, and operational challenges. The industry, in collaboration with the Department of the Interior and other Federal and State agencies, has employed a variety of advanced technologies and creative solutions to operate effectively in these areas, thus providing the environmental stewardship necessary.

In the Aransas National Wildlife Refuge on Texas' Gulf Coast, for example, Conoco has worked collaboratively with the U.S. Fish and Wildlife Service, the National Marine Fisheries Service, and the Texas Parks and Wildlife Park for 60 years to ensure that ongoing operations do not harm the refuge's whooping crane population. Once one of the rarest species in North America, the refuge's whooping crane population has increased in number from 15 to approximately 200 over the last half century. Today, Conoco performs seismic and drilling operations only when the cranes are summering in Canada, avoids the marshlands inhabited by cranes, and protects the wolfberry plants on which they feed.

In Alaska's Kenai National Wildlife Refuge, Unocal Alaska won the Department of Interior's "National Health of the Land" award in 1997 for environmental excellence in its Swanson River field operations. Employing advanced pipeline maintenance, leak detection, and water filtration/treatment technologies, Unocal continues to operate successfully in this beautiful, yet fragile, environment.

Chevron USA Production Company's recent exploratory drilling operation at the Hunter Creek site in Lincoln County, Wyoming, further demonstrates advanced

technology's positive impact on industry performance in sensitive public lands. The Hunter Creek site is located in the Bridger-Teton National Forest—approximately 20 miles from Grand Teton National Park and within the Greater Yellowstone Ecosystem—and is home to a wide variety of sensitive wildlife species, from black bears to bighorn sheep to peregrine falcons. Chevron worked closely with the U.S. Forest Service, the Department of the Interior, the Wyoming Fish and Game Department, and other Federal and State agencies to design and conduct operations with minimal impact on the surrounding habitat and wildlife. Although the site's exploratory well was not a commercial success, Chevron's goal of reducing environmental impacts was achieved.

To minimize surface impacts of equipment mobilization on the area's main access road, the Hunter Creek operation became only the second well in the lower-48 States to be drilled utilizing a helicopter to transport the drilling rig and other heavy equipment to and from the site. The drilling pad was designed to blend in with the surrounding meadows and clearings by carefully locating the site, contouring the area cleared of trees, and leaving some of the site's trees intact.

To enhance site restoration activities, Chevron stockpiled snags, boulders, and stumps so that the site could eventually be returned to its natural state.

To manage drilling wastes, a semi-closed-loop solids removal system was employed, minimizing mud volumes and thus enabling smaller reserve pits. To reduce sedimentation impacts from runoff contact with exposed soil near the pad, the drilling location was enclosed by drain canals, drainage ditches, berms, and containment pit, and capped with four inches of gravel. To further manage operations, Chevron implemented surface and groundwater quality protection plans to ensure protection of surrounding creeks and underground water supplies.

These operations demonstrate the petroleum industry's commitment to environmentally responsible operations on our Nation's public lands. By collaborating with the numerous Federal and State agencies with stewardship responsibilities over these valued areas, the oil and gas industry is today fulfilling its role as protectors of the environment—and advanced technology is playing a large part in this success.

Beyond the Oil Patch

Research and demonstrations of the restoration of sensitive environments have advanced the state of knowledge and understanding of a wide variety of sensitive ecosystems.